MAB-E

(Most Awesome Backpack - Ever)

System Design and Project Plan

Eric Locke
Natalie Nill
Simon Reinhardt
Adrian Villalobos

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System Design

Background

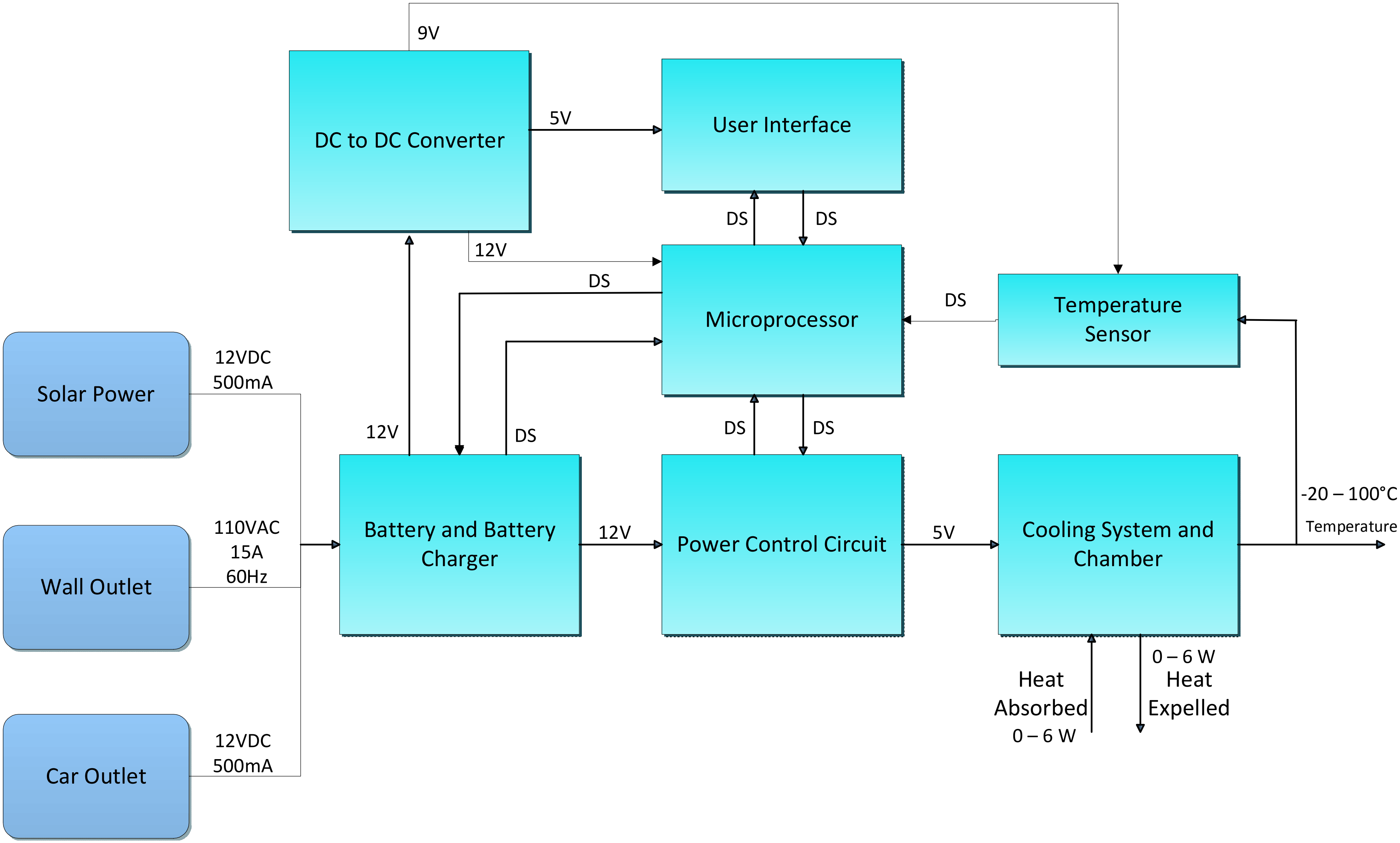
Vaccines have been one of the most beneficial healthcare discoveries of the past couple centuries. Unfortunately, many people are unable to receive vaccines because, among other reasons, health services are unable to reach them while keeping the vaccines cool enough. According to the PATH organization, transporting vaccines in Africa can be extremely challenging because regulating the temperatures of vaccines, while transporting them to rural areas, is difficult and especially challenging in areas without constant power sources. In 2002, over 84,000 people died from Hepatitis B (a vaccine that requires cooling) alone. Some of these deaths are due to the inability of health organizations to transport vaccines to every place they are needed. Many of these organizations are working to raise awareness about this issue and find ways to reach more people. If more people could be reached, thousands of lives could be saved.

There are multiple ways of using alternate power to refrigerate vaccines currently being used. The most predominant include nonelectric/uncontrolled cold packs, kerosene powered refrigeration, and solar power. The cold packs have limited use because they have a maximum cooling time of 48 hours. The kerosene refrigeration is impractical because it requires continuous refueling and is potentially dangerous. Therefore, our team has decided to use solar power because it is a portable and efficient way to solve this problem.

System Overview

There is a need for a better method for transferring vaccines into rural areas of developing nations where power is not easily accessible for refrigeration. There is no developed method that involves continuous refrigeration from a portable, consistent, and environmentally friendly power source. By having a refrigeration system that can be powered during transportation, the ability to distribute vaccines will be greatly increased and the chances of ruining vaccines will be diminished.

Our goal is to create a means of transporting vaccines to remote areas in rural parts of developing countries. The design is a solar powered backpack refrigerator. The device will be driven by a battery which can be recharged by either plugging it into a 110 V AC power outlet or 12 V DC car jack when available, or by a solar panel that is attached to the backpack when on foot. A user interface will allow the user to set the temperature within the insulated chamber and will inform him of the current temperature. It will also warn the user if the temperature ever gets too high so that the ruining of vaccines can be prevented. A microcontroller continuously checks the temperature within the insulated chamber and decides whether it needs to be cooled. The device will weigh less than 37 kg ($\approx$ 82 lbs) and will not exceed a size of 60 cm x 100 cm x 60 cm.



DS Stands for Digital Signal
DS = 0 or 5V and or mA

Functional Decomposition of Blocks

Solar Power: There will be solar panels attached to the unit that will output a minimum of 25W of power to the battery circuit.

Wall Outlet/ Car Outlet: The prototype will be able to run on power from a standard wall outlet in a US home or business, and a standard vehicle dashboard power source.

Battery and Battery Charger: The battery will be able to hold enough energy to run the backpack for 2 hours minimum, and be light enough to keep the backpack from exceeding the weight limit of 37 kg. The battery charger circuit will allow the battery to be charged from any power source connected at the time as well as ensuring that the battery will not be discharged through undesirable sources.

User Interface: The user interface will be a panel on the outside of the unit that displays the chamber temperature and the amount of battery power left. It will also allow the user to input and change the desired temperature range.

Microprocessor: The microprocessor will have the following functions:

1) Read a user input from the user interface specifying a desired temperature range.
2) Read the current temperature inside the chamber and compare that temperature with the user specified temperature. It will then be able to adjust the output from the power control circuit to allow the chamber temperature to reach the user specified temperature range, and then hold that temperature for a minimum of 48 hours.
3) Read an input from the battery circuit and analyze the battery life remaining. Once the battery life is determined, it will output that value to the user interface screen.
4) Keep a time stamped record of the temperature during use and store the values in memory to allow the user to trace the temperature history after use.

Power Control Circuit: The power control circuit will be controlled by the microprocessor and will regulate the amount of power flowing from the battery to the cooling system.

DC to DC Converter: The DC to DC converter will take the power coming from the battery and convert it to the desired input powers for the user interface, the microprocessor, and the temperature sensor.

Temperature Sensor: The temperature sensor will be able to read the temperature inside the cooling chamber to within ±1°C and relay that value to the microcontroller.

Cooling System and Chamber: The cooling chamber will have 35cm x 25cm x 20cm of storage space as well as an insulation layer that will allow restrict heat flow into the chamber. The cooling system will be permanently attached to the chamber and will consist of the thermo-electric cooler, the heat sink, and the ventilation system to displace heat.

Project Plan

Organization and Management

Eric Locke – Eric is a senior level electrical engineering student, and was designated to be the Project leader for this design. He is primarily responsible for selecting and programming the microcontroller that will control all of the functionality of the backpack. He will also be responsible for designing and constructing the user interface that will allow the user to control the backpack. Eric will assist Adrian with general circuit design and all other team members in general project implementation. Finally, he will make sure that the project is moving at the pace needed for its success as well as oversee each team member's work to ensure compatibility and communication between projects.

Adrian Villalobos – Adrian is a senior level electrical engineering student. He is primarily responsible for the power and hardware circuits of the project. These include the battery and battery charger, power control, and DC to DC converter circuits. Adrian will also be responsible for any other circuitry that is needed for the backpack's functionality. Adrian will also assist other members in general device design.

Simon Reinhardt – Simon is a senior level mechanical engineering student. His primary responsibility is to select and design the cooling system for the backpack. This will include analyzing heat flow into and out of the chamber along with Natalie. Simon will also assist Eric with selecting and mounting the temperature sensor. Lastly, he will assist other team members in general project design and engineering decisions.

Natalie Nill – Natalie is a senior level mechanical engineering student. She is primarily responsible for designing and constructing the cooling chamber of the backpack. This will include selecting and applying the insulation that will line the chamber. Natalie will also assist Simon in analyzing heat flow into and out of the chamber. She will assist other team members with general project design and major engineering decisions.

The lists of tasks for each engineer are not all inclusive. Each team member is equipped and able to assist one another in their respective tasks. Because of this, the schedule of tasks is subject to change. Every member is responsible for consistent and thorough documentation of their research, work, and progress. They are also responsible for presenting their data and progress in each A3 status report.

Budget

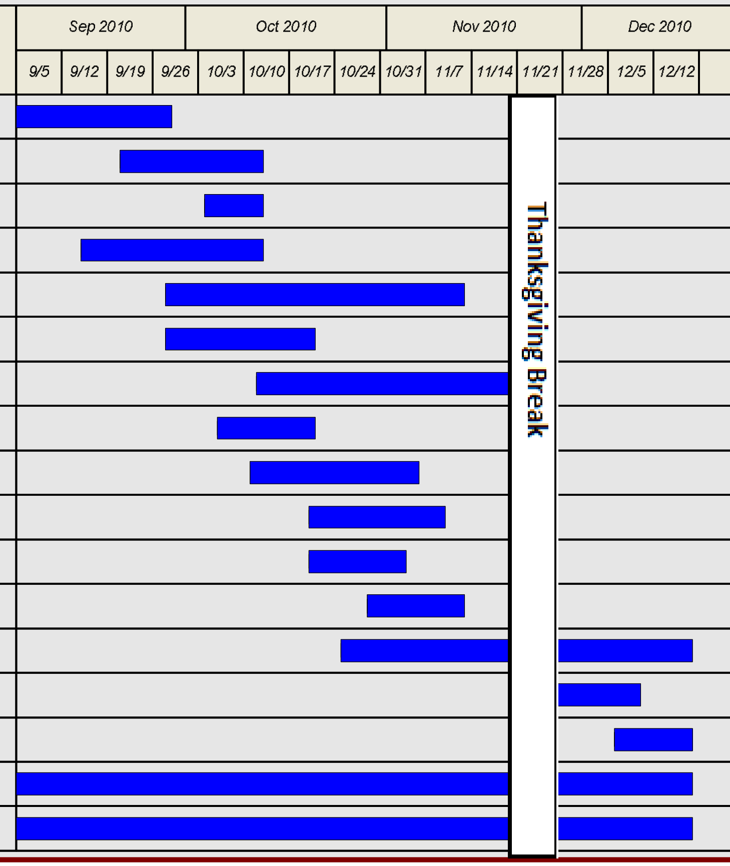
Estimated Cost of Supplies			
Item	**Possible Vendor**	**Cost**	**Date of Estimate**
Insulation	LOWE'S	$37	4-Oct-10
Battery	ATBATT	$99	4-Oct-10
Microprocessor	microchipDIRECT	$0	11-Oct-10
Circuit Board	SUNSTONE	$40	11-Oct-10
LCD Screen	Newark	$13	4-Oct-10
Electrical Components	DIGI KEY	$28	4-Oct-10
Solar Panel	REAL GOODS	$300	4-Oct-10
Thermometer	INSTRUMENTATION2000	$51	4-Oct-10
Fans		$8	4-Oct-10
Thermoelectric coolers(2)	Asia Engineer	$70	4-Oct-10
Miscellaneous	WODERCO	$354	11-Oct-10
Total		**$1,000**	

Work Breakdown Structure – Fall 2010						
Tasks	**Activity**	**Description**	**Deliverables**	**Start/Stop**	**People**	**Resources**
F1.0	Develop Requirements Specification	Document stating the goals of the project	Written document, requirements list	8/30 – 9/28	ALL	Computer
F2.0	Overall Project Design	Develop block diagram, design entire project layout	Block Diagram, major decisions on parts and methods	9/21 – 10/12	ALL	Computer
F2.1	Microcontroller Selection	Select a microcontroller that will meet the needs of the project.	Microcontroller/ Data sheets	10/04 – 10/12	Eric	Computer
F2.2	Cooling System Selection	Select the method of cooling that is the most efficient within budget constraints	Cooling System method	9/15 – 10/12	Simon	Computer
F3.0	Device Design	Design sub-systems of project. Specify inputs and outputs.	Schematics and simulations for each sub-system	9/28 – 11/19	ALL	Computer/ Multisim/ Solidworks
F3.1	Cooling Chamber Design	Decide what material to use and compute heat transfer equations.	Results of heat transfer equations/ material choice	9/28 – 10/20	Natalie	Computer
F3.2	Cooling System Design	Define inputs and outputs of cooling system. Develop a multisim circuit of system	Multisim schematic	10/12 – 11/19	Simon/ Eric	Computer/ Multisim
F3.3	Battery and Battery Charger Circuit Design	Define inputs and outputs of battery and battery charger. Simulate circuit in multisim	Multisim schematic	10/6 – 10/20	Adrian	Computer/ Multisim
F3.4	Temperature Sensor Design	Decide what type of temperature sensor to use and design circuit for sensor	Multisim schematic/ Decision on temperature sensor	10/11 – 11/5	Simon / Adrian	Computer/ Multisim
F3.5	User Interface Design	Design user interface and indicators to be used in the system.	Multisim schematic	10/20 – 11/9	Eric	Computer/ Multisim
F3.6	Power Control Circuit Design	Design circuit to control the power into the cooling system	Multisim schematic	10/20 – 11/3	Adrian	Computer/ Multisim
F3.7	DC to DC Converter Design	Design circuit for the converter that will control power into system devices	Multisim schematic/ decision on DC to DC converter	10/29 – 11/12	Adrian	Computer/ Multisim
F3.8	Program Microcontroller	Develop software for the microcontroller to be able to control the system	Software on Microcontroller	10/25 – 12/17	Eric	Computer
F4.0	System Compilation	Make sure that Sub-systems will be compatible with one another. Find final parts to order	Total System design and all Simulations	11/26 – 12/9	ALL	Computer
F5.0	Final Design	Finalize design for entire system and sub-systems	Documentation, presentation	12/6 – 12/17	ALL	Computer
A1.0	Project Management	Make sure all projects are on schedule and within budget constraints.	Project progress accounted for	8/30 – 12/17	Eric	Communica tion
A2.0	Documentation	Record all design work and progress. Record all research and tests.	Documents, reports, Engineering Notebooks	8/30 – 12/17	ALL	Computer/ Engineering Notebooks

Work Breakdown Structure – Spring 2010						
Tasks	**Activity**	**Description**	**Deliverables**	**Start/Stop**	**People**	**Resources**
S1.0	Parts Assembly and Testing	Assemble Parts. Confirm parts are operational	Working Parts. Test Results	1/18 – 3/11	ALL	Computer/ Test equipment
S1.1	Cooling Chamber	Build Cooling Chamber and apply insulation. Test heat resistance.	Cooling Chamber with insulation. Test results	1/18 – 2/10	Natalie	Work Shop
S1.2	Cooling System	Assemble Cooling System, heat sink, and ventilation system.	Compiled Cooling System	1/25 – 2/21	Simon	Work Shop
S1.3	Battery and Battery Charger Circuit	Create circuit for the battery and battery charger. Test charger and output from battery.	Battery/Battery Charger Circuit. Test Results	2/2 – 2/15	Adrian	Work Shop
S1.4	Temperature Sensor	Create circuit for the Temperature sensor. Test for accuracy.	Temperature Sensor Circuit. Test Results	2/3 – 2/9	Eric/ Simon	Work Shop
S1.5	User Interface	Assemble User Interface. Test LED and screen output. Test communication with microcontroller	User Interface circuit and LEDs. Proof of communication	2/10 – 3/2	Eric	Work Shop
S1.6	Power Control Circuit	Create Power Control circuit. Test for output. Test communication with microcontroller	Power Control Circuit/ Test Results Proof of Communication	2/1 – 2/21	Adrian	Work Shop
S1.7	DC to DC Converter	Create circuit for DC to DC converter. Test outputs.	DC to DC circuit. Test results	2/1 – 2/9	Adrian	Work Shop
S1.8	Program Microcontroller	Develop software for the microcontroller to be able to control the system	Software on Microcontroller	1/18 – 2/21	Eric	Computer
S2.0	Full Frame Assembly	Assemble frame that will house all sub-systems	Full System Frame	1/24 – 2/25	Natalie/ Simon	Work Shop
S3.0	System Integration	Compile all sub-systems into system frame.	Full Frame with Integrated Sub-Systems	2/21 – 4/25	ALL	Work Shop
S4.0	System Testing	Test and verify functionality and compatibility of system as a whole	Test Results	3/21 – 4/25	ALL	Work Shop/ Computer
S5.0	Project Finalization	Final testing and troubleshooting	Finished Prototype	4/26 – 5/9	ALL	Work Shop/ Computer
S6.0	Prototype Presentation	Present completed prototype.	All test results, models, simulation data/ Prototype	5/9 – 5/13	ALL	Computer/ Documentation
A1.0	Project Management	Make sure all projects are on schedule and within budget constraints.	Project progress accounted for	1/18 – 5/13	Eric	Communication
A2.0	Documentation	Record all design work and progress. Record all research and tests.	Documents, reports, Engineering Notebooks	1/18 – 5/13	ALL	Computer/ Engineering Notebooks

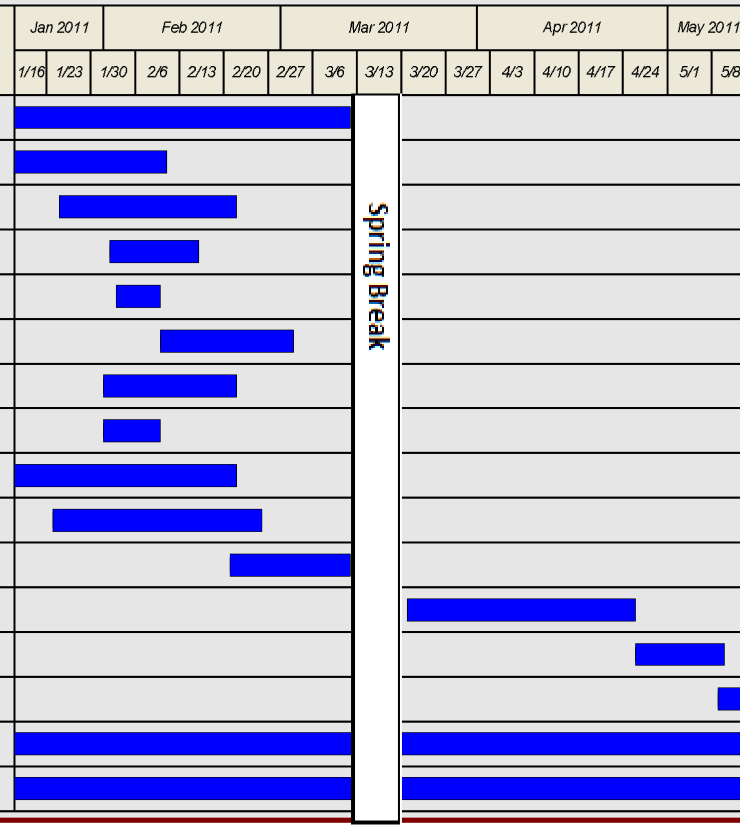
<u>Gantt Chart</u>
Fall 2010

#	ID	Task Description	Start	Finish	Duration
1	F1.0	Develop Requirement Specification	8/30/2010	9/28/2010	4.4w
2	F2.0	Overall System Design	9/21/2010	10/12/2010	3.2w
3	F2.1	Microcontroller Selection	10/4/2010	10/12/2010	1.4w
4	F2.2	Cooling System Selection	9/15/2010	10/12/2010	4w
5	F3.0	Device Design	9/28/2010	11/12/2010	6.8w
6	F3.1	Cooling Chamber Design	9/28/2010	10/20/2010	3.4w
7	F3.2	Cooling System Design	10/12/2010	11/19/2010	5.8w
8	F3.3	Battery and Battery Charger Circuit Design	10/6/2010	10/20/2010	2.2w
9	F3.4	Temperature Sensor Design	10/11/2010	11/5/2010	4w
10	F3.5	User Interface Design	10/20/2010	11/9/2010	3w
11	F3.6	Power Control Circuit Design	10/20/2010	11/3/2010	2.2w
12	F3.7	DC to DC Converter	10/29/2010	11/12/2010	2.2w
13	F3.8	Program Microcontroller	10/25/2010	12/17/2010	8w
14	F4.0	System Compilation	11/26/2010	12/9/2010	2w
15	F5.0	Final Design	12/6/2010	12/17/2010	2w
16	A1.0	Project Managment	8/30/2010	12/17/2010	16w
17	A2.0	Documentation	8/30/2010	12/17/2010	16w

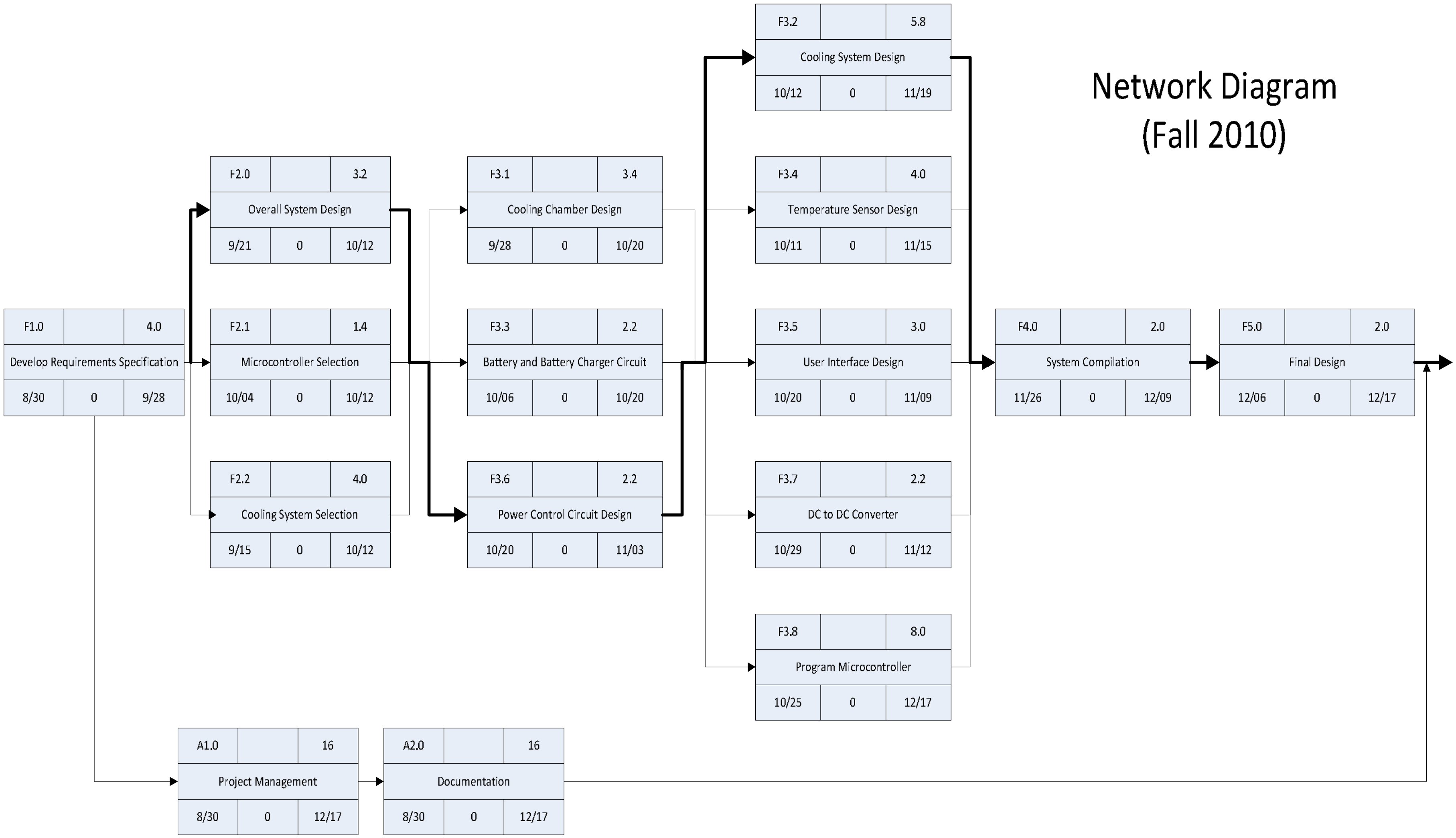


Gantt Chart
Spring 2011

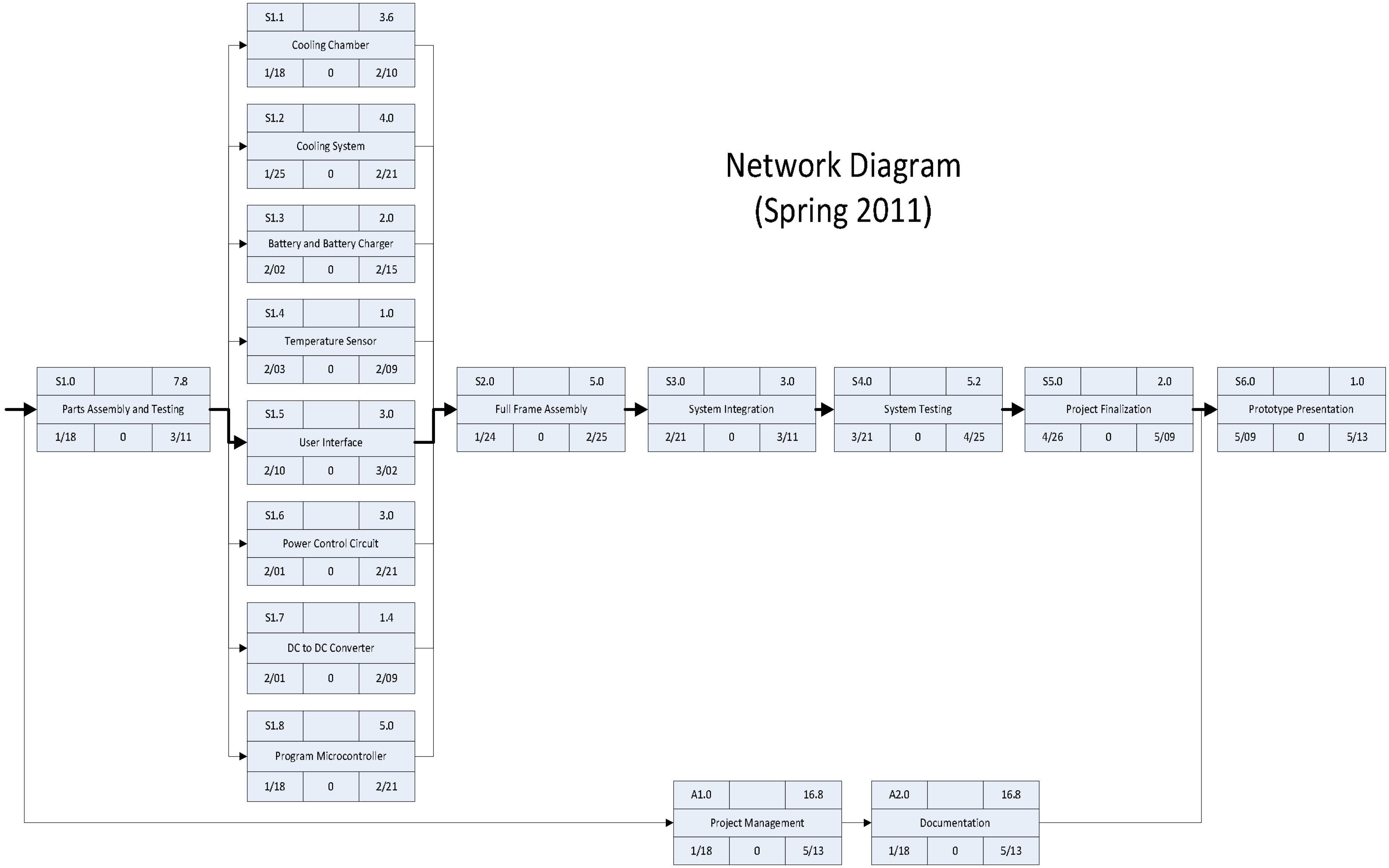
#	ID	Task Name	Start	Finish	Duration
1	S1.0	Parts Assembly and Testing	1/18/2011	3/11/2011	7.8w
2	S1.1	Cooling Chamber	1/18/2011	2/10/2011	3.6w
3	S1.2	Cooling System	1/25/2011	2/21/2011	4w
4	S1.3	Battery and Battery Charger	2/2/2011	2/15/2011	2w
5	S1.4	Temperature Sensor	2/3/2011	2/9/2011	1w
6	S1.5	User Interface	2/10/2011	3/2/2011	3w
7	S1.6	Power Control Circuit	2/1/2011	2/21/2011	3w
8	S1.7	DC to DC Converter	2/1/2011	2/9/2011	1.4w
9	S1.8	Program Microcontroller	1/18/2011	2/21/2011	5w
10	S2.0	Full Frame Assembly	1/24/2011	2/25/2011	5w
11	S3.0	System Integration	2/21/2011	3/11/2011	3w
12	S4.0	System Testing	3/21/2011	4/25/2011	5.2w
13	S5.0	Project Finalization	4/26/2011	5/9/2011	2w
14	S6.0	Prototype Presentation	5/9/2011	5/13/2011	1w
15	A1.0	Project Management	1/18/2011	5/13/2011	16.8w
16	A2.0	Documentation	1/18/2011	5/13/2011	16.8w



Network Diagram (Fall 2010)



Network Diagram (Spring 2011)



Appendices

Appendix A

(Budget References)

From LOWE’S

Dow 1" x 8' x 4' Extruded Polystyrene Insulated Sheathing

1" x 8' x 4' Extruded Polystyrene Insulated Sheathing

- Helps manage energy loss and moisture
- Lightweight and east to handle
- Easy to cut
- Reduces moisture in your home
- Dow 1" x 8' x 4' Extruded Polystyrene Insulated Sheathing

Item #: 14546 | Model #: 202631

Specifications

Insulation Type	Extruded Polystyrene
Thickness (Inches)	1.0
Length (Feet)	4.0
Width (Feet)	8.0
R-Value	5.0

From ATBATT

Amstron - HP 346970-001 Replacement **Battery Replacement HP 346970-001** by

Amstron provides reliable performance in your HP laptop. This precision-engineered Lithium-Ion battery is designed for use in the HP Pavilion ZV5000 series notebooks. Take your work on the road with you without sacrificing performance and productivity with Amstron brand HP laptop batteries.

Specifications:

• Chemistry: Li-Ion

• Rating: 14.8V 6600mAh

• Will Meet or exceed original specifications

• Warranty: 1 Year

From Sunstone circuits

ValueProto® Boards

Sunstone's ValueProto® PCB's offer you an affordable option for ordering small quantities of 2-layer boards. These boards are perfect for special projects that don't require a 24-hour expedite, or if low quantity and value pricing is important. Simply input your dimensions and quantity below, upload your files, and place your order. It's that easy.

- Buy PCBs for as little as $28 shipped
- 2 Layers, up to 2 sides green solder mask with white top side legend optional
- Tin lead finish only
- Minimum trace/space is 0.007" (7 mil)
- 23 pre-set finished hole sizes
- Product only available in the USA. International Orders, try PCBexpress®

- Small boards at a small quantity
- Shape is not limited to rectangles
- Boards shipped within 2 weeks
- Free UPS ground shipping
- Credit card orders only
- 24/7/365 Email support

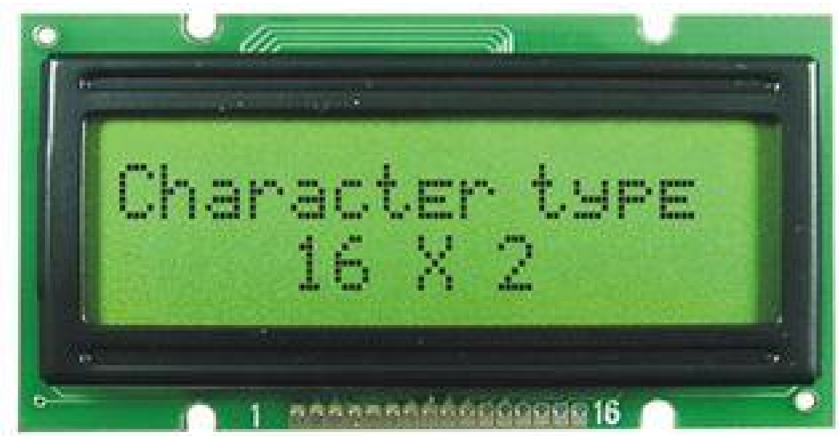
Quote & Order Your ValueProto® PCB

Email Support

Width x Length:	4	x	5	Quantity:	2	Quick Build:	☐	Order Total:	**$145.00**
Shipping Zip Code:	72149								

From Newark

LUMEX - LCM-S01602DTR/M - LCD Alphanumeric Display



LUMEX
Creating LED and LCD Solutions Together™

Manufacturer:
  LUMEX

Newark Part Number:
  19J7668

Manufacturer Part No:
  LCM-S01602DTR/M

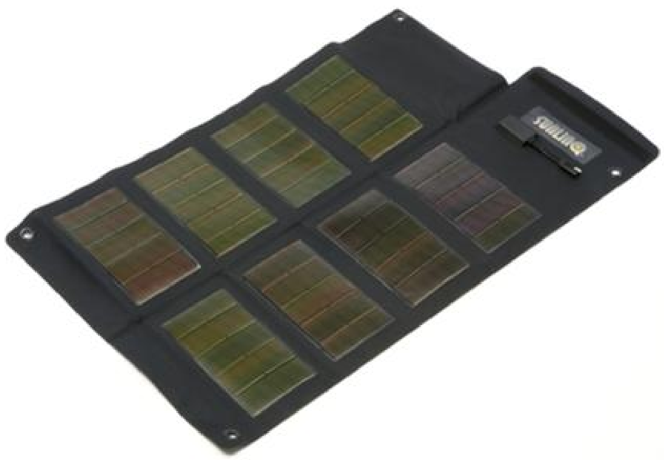
RoHS Compliance : **Yes**

Description

- LCD Alphanumeric Display
- No. of Digits/Alpha:32
- Character Count x Line:16 x 2
- Character Size:5.56mm
- Supply Voltage:5V
- Display Mode:Reflective
- Display Area Width:66mm
- Display Area Height:16mm
- RoHS Compliant: Yes

From Real Goods

Sunlinq 12 Watt Flexible Solar Panel



These weatherproof solar solutions fold to about the size of a paperback book to create a lightweight, portable power station for campers, hikers, boaters and others on the go (not recommended for salt-air conditions). Just open under full sun and charge lanterns, cell phones, GPS units, iPods®, cameras and any other device that has a 12V car adapter. With grommets to attach them to all kinds of gear, they're trail-tough and sized to pack anywhere. 6.5-, 12-, and 25- watt models have a built-in voltage cap to permit a direct charge to small devices and prevent damage from low-light reverse power flows. These three modules also include a connectivity kit with 12V receptacle, 12V vehicle power outlet, battery clamps, 4 in. barrel plug, and 8 ft. extension cable. Use 7-amp charge controller to regulate power flow to batteries and "y" cable to connect multiple panels in parallel. 6.5-watt model is 11"H x 9"W x 1"D folded; 0.45 lbs. 12-watt is 9"H x 5"W x 7⁄10"D; 0.70 lbs. 25-watt is 11"H x 8¼"W x 7⁄10"D; 1.8 lbs. 55-watt (does not come with extra connectivity kit) is 11"H x 9"W x 1"D; 4.4 lbs. USA.

From INTRUMENTATION2000

Supco PT100 Digital Surface HVAC Thermometer

Our Price: $51.49

Supco PT100 Digital Surface HVAC Thermometer

Applications:

- Superheat, Evaporator Temperatures
- Plate and Condensing Temperatures
- Measure Air Inlet, Outlet and Surrounding Air

Features:

- Ultra Sensitive Air and Surface Reading Probe, Quick Response
- Super Accurate RTD Sensor, 0.2 Deg Surface, 1 Deg Air
- Large LCD Display - (7/16" High, 3-1/2 Digits, 1/10 Deg Increments)
- Now Four Models to Chose from Reads Temperatures from:
  - -40 Deg F to +199.9 Deg F (PT100)
  - -40 Deg C to 93.28 Deg C (PT100C)
  - -40 Deg F to +250 Deg F (PT100H)
  - -40 Deg C to 120 Deg C (PT100HC)
- Battery Operated (Requires Standard 9V Battery)
- Dimensions: 1 1/2" x 6 3/4" x 7/8"

Appendix B
(Requirements Specification Document)

Requirements Specification

Solar Powered Backpack Refrigeration Unit

Adrian Villalobos
Eric Locke
Natalie Nill
Simon Reinhardt

Overview

Vaccines have been one of the most beneficial healthcare discoveries of the past couple centuries. Unfortunately, many people are unable to receive vaccines because, among other reasons, health services are unable to reach them while keeping the vaccines cool enough. According to the PATH organization, transporting vaccines in Africa can be extremely challenging because regulating the temperatures of vaccines, while transporting them to rural areas, is difficult and especially challenging in areas without constant power sources[1]. In 2002, over 84,000 people died from Hepatitis B (a vaccine that requires cooling) alone[2]. Some of these deaths are due to the inability of health organizations to transport vaccines to every place they are needed. Many of these organizations are working to raise awareness about this issue and find ways to reach more people. If more people could be reached, thousands of lives could be saved.

There are multiple ways of using alternate power to refrigerate vaccines currently being used. The most predominant include nonelectric/uncontrolled cold packs, kerosene powered refrigeration, and solar power. The cold packs have limited use because they have a maximum cooling time of 48 hours. The kerosene refrigeration is impractical because it requires continuous refueling and is potentially dangerous. Therefore, our team has decided to use solar power because it is a portable, reliable, and an efficient way to solve this problem.

Problem Statement

There is a need for a better method for transferring vaccines into rural areas of developing nations where power is not easily accessible for refrigeration. There is no developed method that involves continuous refrigeration from a portable, consistent, and environmentally friendly power source. By having a refrigeration system that can be powered during transportation, the ability to distribute vaccines will be greatly increased and the chances of ruining vaccines will be diminished.

[1] "PATH: Cold Chain." *PATH: A Catalyst for Global Health*. May 2010. Web. 13 Sept. 2010. <http://www.path.org/projects/cold-chain.php>.

[2] "Statistics about Hepatitis B - WrongDiagnosis.com." *Wrong Diagnosis*. Aug. 2010. Web. 20 Sept. 2010. <http://www.wrongdiagnosis.com/h/hepatitis_b/stats.htm>.

Operational Description:

Before Transportation:

Before using the refrigeration backpack to transport vaccines any distance, the target temperature must be met inside the refrigeration chamber. This can be achieved by one of four ways

1. External Power: The pack can be cooled by using external power from any outlet that has an output standard to the US or African power grid.
2. Cooling Packs: The backpack can be cooled by placing cold packs, such as those used to keep non-electric vaccine shipping boxes cool, inside the chamber.
3. Refrigerator: The backpack can be cooled by placing the chamber inside a larger refrigerator or freezer until the target temperature is reached.
4. Solar Power: The backpack can be cooled beforehand using solar power. This method may require time to charge the packs batteries and cool the chamber.

Also, the batteries must be charged before the vaccines are transported any distance. This can be accomplished by either using an external power source and/or using solar power to charge the batteries. For a faster charge time, the batteries can be charged while the cooling system is off to send all power from the solar panels or external source to the batteries.

The user will be able to select the allowable temperature range via the user interface. First select the mode for temperature selection, then type in the lowest allowable temperature and then the highest allowable temperature in that order when prompted on the screen.

During Transportation:

IMPORTANT- Avoid opening the refrigerator door until the destination has been reached as this will compromise the environment of the vaccines and might deplete the backpacks energy supply prematurely.

The user will be able to monitor the current temperature inside the refrigerator via the indicator mounted on the outside of the refrigeration chamber. They will also be able to read the approximate battery life reading that will inform them as to the amount of energy currently in the pack in the same screen.

The user should make sure that the solar panels are clear of anything that may block them from the sun when possible.

After Transportation:

When the destination is reached the user should transfer the vaccines to a secure environment to be used as needed. The backpack should remain in the refrigeration mode until vaccines are no longer stored in the chamber.

Technical Requirements

- The unit will cool a chamber within the backpack and maintain it at a temperature range between 2℃ and 8℃ (35°F and 46°F), for a minimum of 48 hours, at an average ambient temperature up to 30°C (86°F), while stationary.
- The temperature inside the refrigeration chamber will be read and relayed so it can be displayed on the outside of the unit. The temperature sensor will have a maximum resolution range of $\pm$ 1℃, and will cover a temperature range of at least 0°C to 30°C (32°F to 86°F).
- The entire unit will weigh less than 37 kg (≈ 82 lbs).
- The backpack will not exceed a size of 60 cm x 100 cm x 60 cm.
- The refrigeration system will be controlled to within the specified temperature range.
- The unit will be able to measure the temperature inside the chamber to within $\pm$ 1℃.
- The unit will be able to control the temperature inside the chamber to within$\pm$ 3℃.
- There will be a user interface used to control the refrigeration system. It will include: an on/off switch, a digital temperature display, a temperature control interface, and battery status indicators.
- The unit will have a frame that can perform while being transported on foot and by vehicle.
- All systems will operate in a safe manner that will pose no threat of harm to the users. Temperatures will not go above 50°C or below -30°C, voltages will not exceed 30 V DC, and moving parts will be protected by a grill.

Deliverables

- User's Manual
- Technical Drawings and Analysis of Hardware
- Schematic of Circuit with Simulation Results
- Code and Flowcharts
- Report of Testing
- Parts List with Budget
- Final Technical Report
- Solar Powered Refrigeration Backpack

Preliminary Test Plan

- Four healthy individuals, with a minimum height of 1.6 m (≈ 63 inches) and weight of 54 kg (≈ 120 lbs), will be able to pick up, put on, and take off the backpack with the assistance of one other individual.
- A performance test will be conducted. The backpack will be taken on a mile hike then will immediately be put into a ventilation chamber for a 48 hour period. It will be tested at temperatures between 22°C and 30°C (≈ 72°F and 86°F). The solar panels will be exposed to two cycles of simulated sunlight for 12 hours then darkness for 12 hours. The maximum and minimum temperatures will be recorded over that period. This test will be executed three times.

- Temperature gauge will be tested to insure accurate (within $\pm$ 1°C) temperature readings inside the chamber.
- Backpack will be weighed to insure it does not exceed the maximum weight.

Attachments
The following attachments come from the site:
"Centers for Disease Control and Prevention." Web. 13 Sept 2010.

Guidelines for Maintaining and Managing the Vaccine Cold Chain

In February 2002, the Advisory Committee on Immunization Practices (ACIP) and American Academy of Family Physicians (AAFP) released their revised General Recommendations on Immunization (*1*), which included recommendations on the storage and handling of immunobiologics. Because of increased concern over the potential for errors with the vaccine cold chain (i.e., maintaining proper vaccine temperatures during storage and handling to preserve potency), this notice advises vaccine providers of the importance of proper cold chain management practices. This report describes proper storage units and storage temperatures, outlines appropriate temperature-monitoring practices, and recommends steps for evaluating a temperature-monitoring program. The success of efforts against vaccine-preventable diseases is attributable in part to proper storage and handling of vaccines. Exposure of vaccines to temperatures outside the recommended ranges can affect potency adversely, thereby reducing protection from vaccine-preventable diseases (*1*). Good practices to maintain proper vaccine storage and handling can ensure that the full benefit of immunization is realized.

Recommended Storage Temperatures

The majority of commonly recommended vaccines require storage temperatures of 35°F--46°F (2°C--8°C) and must not be exposed to freezing temperatures. Introduction of varicella vaccine in 1995 and of live attenuated influenza vaccine (LAIV) more recently increased the complexity of vaccine storage. Both varicella vaccine and LAIV must be stored in a continuously frozen state ≤5°F (-15°C) with no freeze-thaw cycles (Table 1). In recent years, instances of improper vaccine storage have been reported. An estimated 17%--37% of providers expose vaccines to improper storage temperatures, and refrigerator temperatures are more commonly kept too cold than too warm (*2,3*).

Freezing temperatures can irreversibly reduce the potency of vaccines required to be stored at 35°F--46°F (2°C--8°C). Certain freeze-sensitive vaccines contain an aluminum adjuvant that precipitates when exposed to freezing temperatures. This results in loss of the adjuvant effect and vaccine potency (*4*). Physical changes are not always apparent after exposure to freezing temperatures and visible signs of freezing are not necessary to result in a decrease in vaccine potency.

Although the potency of the majority of vaccines can be affected adversely by storage temperatures that are too warm, these effects are usually more gradual, predictable, and smaller in magnitude than losses from temperatures that are too cold. In contrast, varicella vaccine and LAIV are required to be stored in continuously frozen states and lose potency when stored above the recommended temperature range.

Vaccine Storage Requirements

Vaccine storage units must be selected carefully and used properly. A combination refrigerator/freezer unit sold for home use is acceptable for vaccine storage if the refrigerator and freezer compartments each have a separate door. However, vaccines should not be stored near the cold air outlet from the freezer to the refrigerator. Many combination units cool the refrigerator compartment by using air from the freezer compartment. In these units, the freezer thermostat controls freezer temperature while the refrigerator thermostat controls the volume of freezer temperature air entering the refrigerator. This can result in different temperature zones within the refrigerator.

Refrigerators without freezers and stand-alone freezers usually perform better at maintaining the precise temperatures required for vaccine storage, and such single-purpose units sold for home use are less expensive alternatives to medical specialty equipment. Any refrigerator or freezer used for vaccine storage must maintain the required temperature range year-round, be large enough to hold the year's largest inventory, and be dedicated to storage of biologics (i.e., food or beverages should not be stored in vaccine storage units). In addition, vaccines should be stored centrally in the refrigerator or freezer, not in the door or on the bottom of the storage unit, and sufficiently away from walls to allow air to circulate.

Temperature Monitoring

Proper temperature monitoring is key to proper cold chain management. Thermometers should be placed in a central location in the storage unit, adjacent to the vaccine. Temperatures should be read and documented twice each day, once when the office or clinic opens and once at the end of the day. Temperature logs should be kept on file for $\geq$3 years, unless state statutes or rules require a longer period. Immediate action must be taken to correct storage temperatures that are outside the recommended ranges. Mishandled vaccines should not be administered.

One person should be assigned primary responsibility for maintaining temperature logs, along with one backup person. Temperature logs should be reviewed by the backup person at least weekly. All staff members working with vaccines should be familiar with proper temperature monitoring.

Different types of thermometers can be used, including standard fluid-filled, min-max, and continuous chart recorder thermometers (Table 2). Standard fluid-filled thermometers are the simplest and least expensive products, but some models might perform poorly. Product temperature thermometers (i.e., those encased in biosafe liquids) might reflect vaccine temperature more accurately. Min-max thermometers monitor the temperature range. Continuous chart recorder thermometers monitor temperature range and duration and can be recalibrated at specified intervals. All thermometers used for monitoring vaccine storage temperatures should be calibrated and certified by an appropriate agency (e.g., National Institute of Standards and Technology). In addition, temperature indicators (e.g., Freeze Watch™ [3M, St. Paul, Minnesota] or ColdMark™ [Cold Ice, Inc., Oakland, California]) can be

considered as a backup monitoring system (*5*); however, such indicators should not be used as a substitute for twice daily temperature readings and documentation.

All medical care providers who administer vaccines should evaluate their cold chain maintenance and management to ensure that 1) designated personnel and backup personnel have written duties and are trained in vaccine storage and handling; 2) accurate thermometers are placed properly in all vaccine storage units and any limitations of the storage system are fully known; 3) vaccines are placed properly within the refrigerator or freezer in which proper temperatures are maintained; 4) temperature logs are reviewed for completeness and any deviations from recommended temperature ranges; 5) any out-of-range temperatures prompt immediate action to fix the problem, with results of these actions documented; 6) any vaccines exposed to out-of-range temperatures are marked "do not use" and isolated physically; 7) when a problem is discovered, the exposed vaccine is maintained at proper temperatures while state or local health departments, or the vaccine manufacturers, are contacted for guidance; and 8) written emergency retrieval and storage procedures are in place in case of equipment failures or power outages. Around-the-clock monitoring systems might be considered to alert staff to after-hours emergencies, particularly if large vaccine inventories are maintained.

Additional information on vaccine storage and handling is available from the Immunization Action Coalition at http://www.immunize.org/izpractices/index.htm. Links to state and local health departments are available at http://www.cdc.gov/other.htm. Especially detailed guidelines from the Commonwealth of Australia on vaccine storage and handling, vaccine storage units, temperature monitoring, and stability of vaccines at different temperatures (*6*) are available at http://immunise.health.gov.au/cool.pdf.

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TABLE 1. Vaccine storage temperature requirements				
35°F-46°F (2°C-8°C)			**≤5°F (-15°C)**	
Instructions	**Vaccine**	**Instructions**	**Instructions**	**Vaccine**
Do not freeze or expose the freezing temperatures.	Diphteria-, tetanus, or pertussis-containning vaccines (DT, DTaP, Td) Haemophilus conjugate vaccine (Hib)* Hepatitis A (HepA) and hepatitis B (HepB) vaccines Inactivated polio vaccine (IPV) Measles, mumps, and rubella vaccine (MMR) in the lyophilized (freeze-dried) state† Meningoccoccal polysaccharide vaccine Pneumococcal conjugate vaccine (PVC) Pneumococcal polysaccharide vaccine (PPV) Trivalent inactivated inflenza vaccine (TIV)		Maintain in continuosly frozen state with no freeze-thaw cycles. Contact state or local health department or manufacturer for guidance on vaccines exposed to temperatures above the recommended range.	Live attenuated influenza vaccine (LAIV)

*ActHIB® (Aventis Pasteur, Lyon, France) in the lyophilized state is not expected to be affected detrimentally by freezing temperatures, although nodata are available.
†MMR in the lyophilized state is not affected detrimentally by freezing temperatures.

TABLE 2. **Comparison of thermometers used to monitor avccine temperatures**

Thermometer type	Advantages	Disadvantages
Standard fluid-filled	Inexpensive and simple to use. Thermometers encased in biosafe liquids can reflect vaccine temperatures more accurately.	Less accurate (+/-1°C). No information on duration of out of specification exposure. No information on min/max temperatures. Cannot be recalibrated. Inexpensive models might perform poorly.
Min-max	inexpensive Monitors temperature range.	Less accurate (+/-1°C). No information on duration of out of specification exposure. Cannot be recalibrated.
Continuous chart recorder	Most accurate Continuous 24-hour readings of temperature range and duration. Can be recalibrated at regular intervals.	Most expensive. Requires most training and maintenance.